TECHNICAL REPORT 164

AIR WEATHER SERVICE

ESTIMATING THE PROBABILITY OF OPERATIONALLY-CRITICAL WIND SPEEDS AFFECTING AN AIR BASE DURING THE PASSAGE OF A TROPICAL CYCLONE

By

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PREFACE

A forecast of a tropical cyclone to pass in the vicinity of a base requires certain decisions to be made, such as whether to tie down or evacuate aircraft, delay construction projects, remove missiles from firing pads, etc. A decision to take such protective action is based primarily on the expectancy of occurrence of wind speeds above a critical value considered hazardous to that particular installation. In order to balance the cost of protection against the damage incurred by an unprotected base, the commander must know the probability of his installation being struck by above-critical wind speeds during the passage of the storm.

In June 1958, Air Weather Service published a technical report [1] which outlined a method for computing the total probability of above-critical wind speeds affecting an airbase at some time during the passage of a hurricane or typhoon. Shortly thereafter, the 1st Weather Wing [2] developed a technique for obtaining the instantaneous probability of strong winds affecting a base at each hour during the storm's passage. In 1961, the Air Force Missile Test Center at Patrick AFB [3] employed a somewhat different approach to obtain the hour-by-hour instantaneous probability.

Inasmuch as an estimate of both the total and hourly probabilities of a base being affected by above-critical winds would be of value to the various activities on the base, it was decided to prepare a new report to include both techniques. The approach used in this new report incorporates some features from each of the three previous studies, plus certain new techniques to provide a more consistent solution to the entire problem.

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31 August 1962

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ESTIMATING THE PROBABILITY OF OPERATIONALLY-CRITICAL WIND SPEEDS AFFECTING AN AIR BASE DURING THE PASSAGE OF A TROPICAL CYCLONE

SECTION A — INTRODUCTION

Information Required for Forecasting Probability of Above-Critical Wind Speeds. Whenever a tropical cyclone[1] (hurricane or typhoon) is forecast to pass in the vicinity of an air base, it is useful to have an estimate of the probability of the base being affected by wind speeds above a specified critical value. This probability depends on the proximity of the forecast storm track to the base, the size of the area of above-critical winds surrounding the storm center, and the forecast accuracy. Specifically, the forecaster needs the following four pieces of information: (1) the forecast position of the storm center with respect to the base, (2) an estimate of the size and distribution of the errors in forecasting this position, (3) the forecast position of the critical isotach with respect to the storm center, and (4) an estimate of the error in forecasting this position.

Items (1) and (3) above are obtainable from the routine cyclone forecast, and item (2) has previously been computed from several years of hurricane and typhoon forecast verifications. However, no verification data are available regarding forecasts of the critical isotach. Consequently, item (4) has arbitrarily been assumed equal to zero, or at least negligible in comparison to item (2). This amounts to saying that the position of the critical isotach with respect to the storm center is known at time zero, and that this relative position can be forecast with negligible error at any time in the future. The validity of this assumption is discussed in the next subsection.

Errors Inherent in the Critical-isotach Forecast. Obviously, it is not possible either to know or to forecast the position of the critical isotach with absolutely no error. To begin with, the shape of the isotachs may be irregular and, since at best only spot wind measurements are made, the exact outline of the isotach is unknown even at observation time. Secondly, it is difficult to assess the surface wind from the flight altitude of a reconnaissance aircraft. The surface wind usually differs significantly from the flight-level wind, the discrepancy being greater the higher the flight altitude. A fairly good estimate of the surface wind can be made from observations of the state of the sea, especially at surface wind speeds around 50 knots, but the sea is frequently obscured by low clouds, particularly in the case of high-altitude observations. Thirdly, even if the location of the critical isotach were known exactly at time zero, it would be difficult to predict accurately future changes in its shape and position. At present, as a safety factor, the area encompassed by specific isotachs is usually arbitrarily enlarged in hurricane forecasts. Finally, it is anticipated that the forthcoming use of high-level WB-47 reconnaissance aircraft will make accurate observations of surface wind speeds even more difficult than they are today.

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[1] In this report, the tropical cyclones of concern are those with wind speeds significantly in excess of 50 knots. The term *tropical storm* is used here in its generic sense synonymous to tropical cyclone (and not in the restricted U.S. operational meaning of a tropical cyclone with winds of 35-64 knots)

On the other side of the picture, independent errors, such as the error in the forecast position of the storm center and the error in the position of the critical isotach with respect to the storm center, do not add directly, but as the square root of the sum of the squares. Thus, if the standard error in forecasting the position of the storm center is 100 miles and the error of the isotach with respect to the storm center is 50 miles, the total isotach forecast error is not 150 miles but $(100^2 + 50^2)^{1/2} = 112$ miles.

Because of the secondary importance of the isotach-position error and because no verification data are available for computing its size, this study has assumed it to be negligible, and considers only the forecast error of the storm center itself. Since in many cases this assumption will result in an underestimate of the total isotach forecast error, the resulting probabilities can only be considered as approximate.

Errors in Forecasting the Position of the Storm Center.

When a meteorologist attempts to predict any parameter, including the location of a storm center at the end of a specified period, he seldom expects to hit his forecast exactly. Consequently, in order to make the best operational use of the forecast, the user must have some idea of the range of errors to be expected. In this study, the distribution of errors was obtained by comparing the forecast positions of the storm centers over a period of years with the actual verifying positions [1]. In Figure 1, Point 0 represents the superimposed observed positions of a large number of storm centers, while the dots represent the corresponding forecast positions at verification time. The forecast error in one case is shown by the vector error from O to P.

It has been found experimentally that the distribution of the dots about the center Point O corresponds fairly well to the so-called *circular normal distribution*. In this distribution, the percentage of points which fall inside a circle of any given radius r is given by the expression:

$$P = 100 \left[1 - \exp \left(- \frac{r^2}{\sigma_v^2} \right) \right].$$

A graph of this function is shown as Curve (a) in Figure 2. The term σ_v is the so-called *standard vector error*, and (since the mean vector error is approximately zero) is equal to the root-mean-square (rms) value of all the individual forecast errors. Circles with radii of $1\sigma_v$ and $2\sigma_v$ have been drawn on Figure 1.

In a circular normal distribution, approximately 63% of the dots will fall within the $1\sigma_v$ circle, 98% within $2\sigma_v$, etc. (Note that these percentages differ from those of the more familiar linear normal distribution discussed below.) Similarly, when a single forecast position is issued, the probability that the storm will actually lie within a distance of $1\sigma_v$ from the forecast position is 63%; within $2\sigma_v$, 98%; etc.

In addition to the standard vector error and the circular normal distribution, this study will also make use of the *standard component error* and the *linear normal distribution*. Any vector, such as an error vector, can be resolved into two perpendicular components. In Figure 3, r represents the same error vector shown in Figure 1, and x and y represent its components parallel and perpendicular to the storm track. Just as the standard vector error is equal to the rms value of all values of r (i.e., $\sigma_v = \sqrt{\Sigma r^2/N}$), the two standard component errors are $\sigma_x = \sqrt{\Sigma x^2/N}$ and $\sigma_y = \sqrt{\Sigma y^2/N}$. From the right-triangle rule, it is clear that $\sigma_v^2 = \sigma_x^2 + \sigma_y^2$. Furthermore, symmetry considerations show that $\sigma_x = \sigma_y = \sigma_n$. (The subscript n is frequently used to refer to components, and will so be used in this report.) Consequently, $\sigma_v^2 = 2\sigma_n^2$, and $\sigma_n = \sigma_v/\sqrt{2} = 0.707\,\sigma_v$.

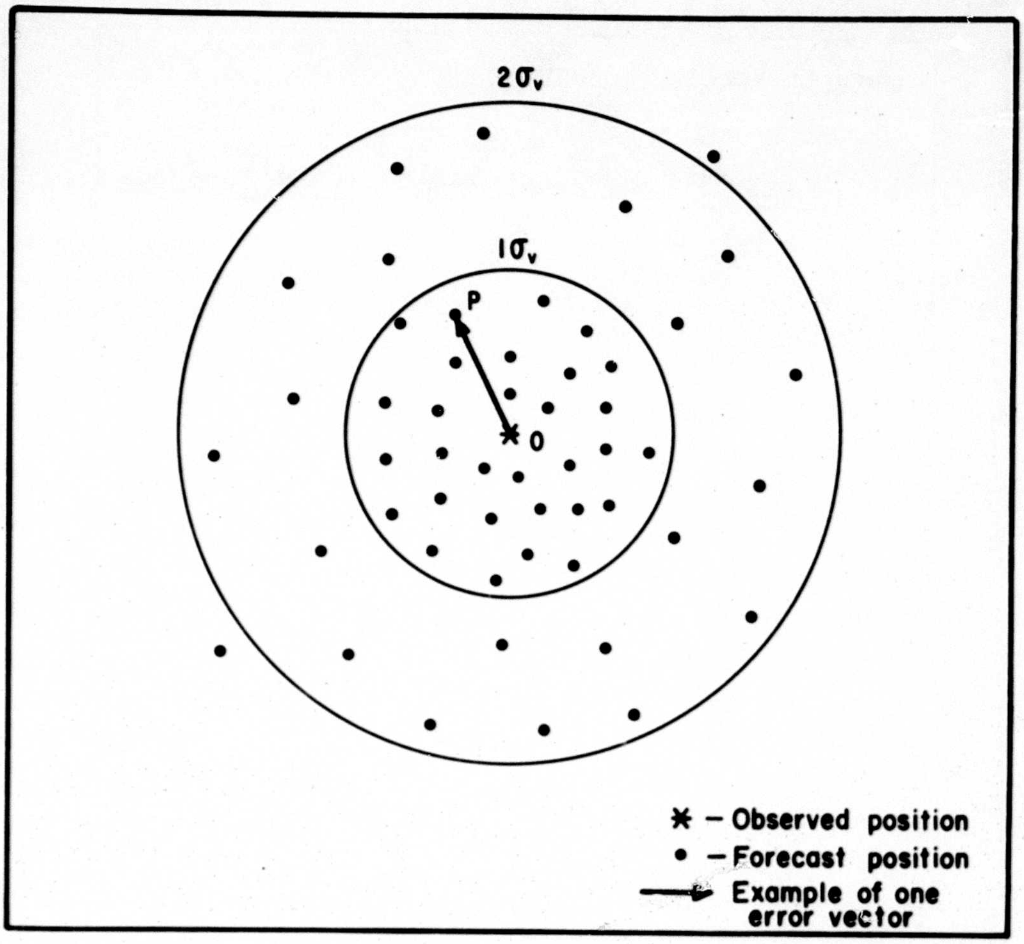

Figure 1 – Comparison of actual and forecast positions of storm center at end of forecast period. Circles shown have radii of one and two standard vector errors, respectively.

Whereas the probability of a storm center falling within a circle of a given radius about the forecast position varies in accordance with the circular normal distribution, the probability of it falling within a given distance to the right or left of the forecast track varies in accordance with the linear normal distribution. Thus, approximately 34% of the cases would be within the zone bounded by the track and a distance equal to $1\sigma_n$ to either side of the track, 68% would fall between $\pm 1\sigma_n$, 95% between $\pm 2\sigma_n$, etc.(curves b and c, Figure 2).

As stated earlier, the standard vector error of forecasting the position of the cyclone centers was computed from several years of actual forecast data. It was found that the error varied with several factors, the most important being the geographical area under consideration. The errors were particularly large in those latitudes where recurvature was most likely to occur.

The values shown in Table 1 were taken from *AWS TR 105-146* [1]. The standard vector errors for the Atlantic-Caribbean area were derived from the 1955-1956 hurricane seasons, and the Pacific data from the years 1945-1954. It is seen that the errors increased about linearly with time. The standard component errors were obtained by multiplying each of the standard

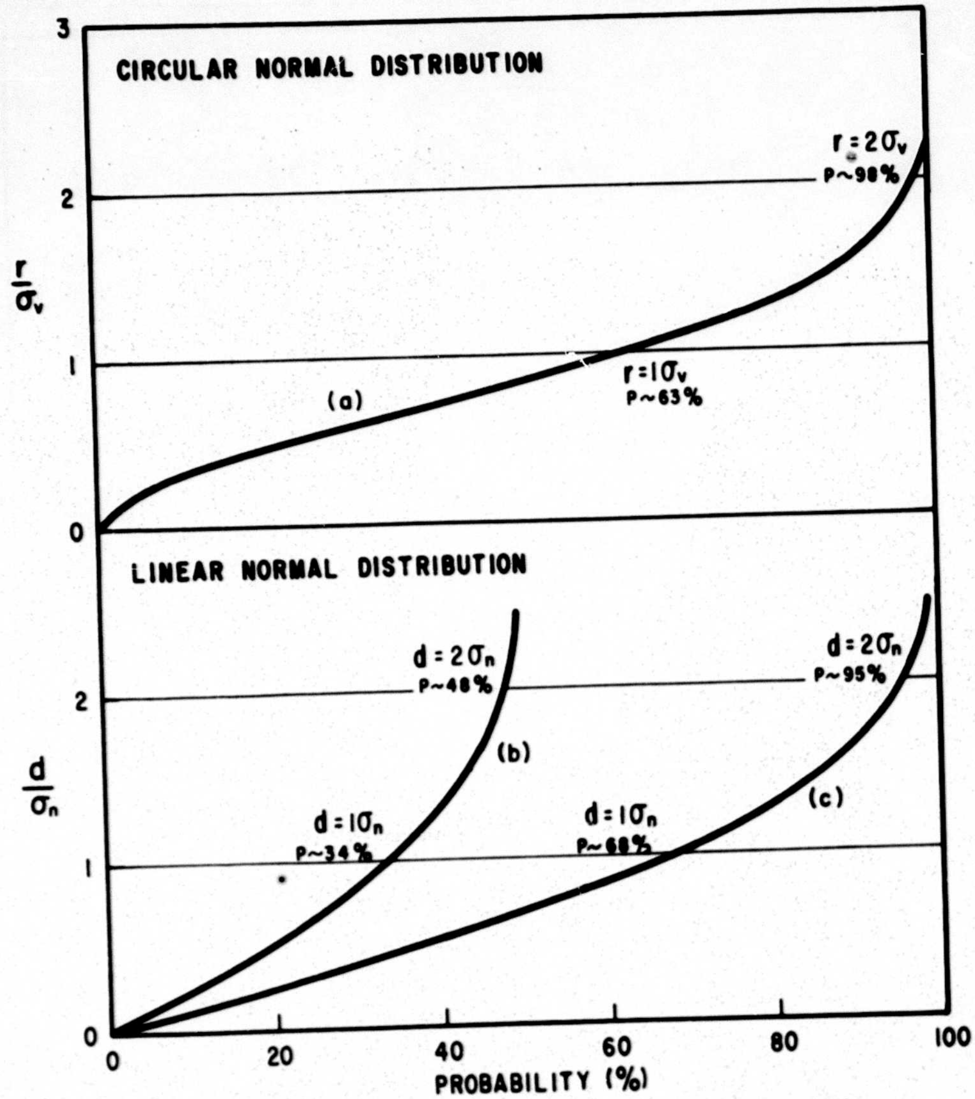

Figure 2 — Probability of a point: (a) falling within a circle of radius r centered at the forecast position of the storm center; (b) lying between the forecast track and a distance d to one side of the track; (c) lying between two lines parallel to, and at distance d on each side of, the forecast track.

vector errors by 0.707. More recent data confirm that the values in Table 1 are sufficiently representative for operational use today. However, studies currently being made by the U.S. Navy and the National Hurricane Research Project indicate that the error values in the Atlantic-Caribbean area may have a latitudinal variation similar to that in the Pacific, with smaller errors in the south, larger in the north. At some future date, therefore, it may prove advisable to revise the nomograms for this region.

Types of Probability Forecasts.

Two types of probability forecasts would aid personnel to take proper action when a storm is forecast for the area of interest. First, and perhaps most important, is the probability that at some time during the passage of the storm the location will be

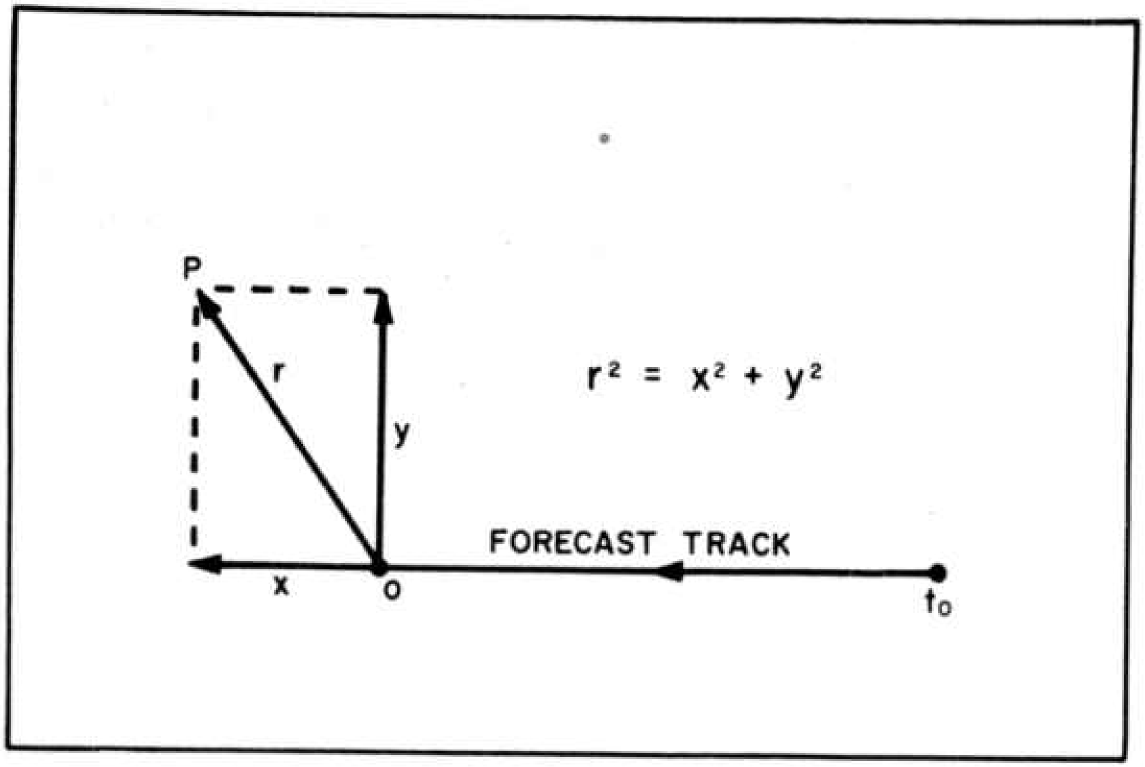

Figure 3 — Relationship between the vector error r, and its x and y components.

TABLE 1

Standard errors (in n. mi.) of hurricane and typhoon forecasts.

Area	Length of Forecast Period (hrs)					
	12		24		36	
	σ_v	σ_n	σ_v	σ_n	σ_v	σ_n
N. Atlantic & Caribbean	81	57	135	96	--	--
N. Pacific <20°N	96	68	172	122	250	177
N. Pacific 20-30°N	119	84	211	149	306	216
N. Pacific >30°N	130	92	233	165	337	238

affected by above-critical wind speeds. This is called the overall or *total probability* (P_t). Second is the probability that the station will be under the influence of strong winds at a specific time, called the *instantaneous probability* (P_i). For example, the storm center might be forecast to pass 70 miles north of a station at 0600Z on 28 August, with a total probability of 35% of affecting the station with above-critical winds. The instantaneous probability, on the other hand, might have values such as 7% at 28/0300Z, 8% at 28/0600Z, 7% at 28/0900Z, etc. A graph of these values would give the hour-by-hour probability of the base being affected at any specific time. Unfortunately, the values of P_t and P_i cannot be obtained from each other, but, as shown in the following Sections, must be computed independently.

SECTION B – THE TOTAL PROBABILITY OF ABOVE-CRITICAL WINDS AFFECTING THE BASE

Explanation of Technique for Determining Total Probability.

In order to determine the total probability (P_t) of the station being affected by above-critical wind speeds at some time during the passage of the storm, the technique illustrated in Figure 4 may be used. For simplicity, the forecast storm track is shown as a straight line. Point P represents the forecast position of the storm center at its nearest approach to the station O, in this case at 24 hours. The critical-wind isotach has been assumed to be a circle centered over the storm center; for purposes of computation it has been constructed about Point O. Thus, if the storm center enters the circular area about Point O, it will influence the base with above-critical winds. The question, then, is to calculate the probability that the storm center will enter this area.

In Figure 4, the slanting lines, E and F, have been drawn from the origin (t = 0) tangent to the two sides of the critical isotach circle. Assuming straight-line trajectories, it is obvious that these lines encompass the tracks of all storms that have already entered, or will enter, the critical area. Actually, the straight-line-trajectory restriction is unnecessary. Inasmuch as the percentage of cases between the two lines is fixed by the normal distribution relationship, one storm must enter the area between the two lines for each one that leaves. Thus, to obtain the probability of a base being affected by a given storm, it is merely necessary to determine the probability that at any given time its track will fall between lines E and F.

Unfortunately, it is difficult to make an exact mathematical computation of this probability; however, it can be approximated in a roundabout fashion, as follows. Straight lines (G and H, Figure 4) are drawn parallel to the forecast storm track, tangent to the critical-isotach circle; the area between is cross-hatched. By determining the distance *(d)* of lines G and H from the track in units of σ_n for the time of interest (t_{24} in this case), the probability of the storm lying within the cross-hatched area at that time can be determined from Figure 2(b). In the simplified example used here, a critical-isotach area has been assumed such that its nearest and farthest boundaries exactly equal the 24-hour values of $1\sigma_n$ and $2\sigma_n$, respectively. Figure 2(b) shows that there is a 34% chance of the storm lying between the track and the line $d = 1\sigma_n$, a 48% chance that it will lie between the track and the line $d = 2\sigma_n$, giving a 14% chance that at t_{24} the storm will lie somewhere within the cross-hatched area.

A comparison can now be made of the probability at time t_{24} of the storm lying within the cross-hatched area with the probability of the storm lying between the slanting lines,

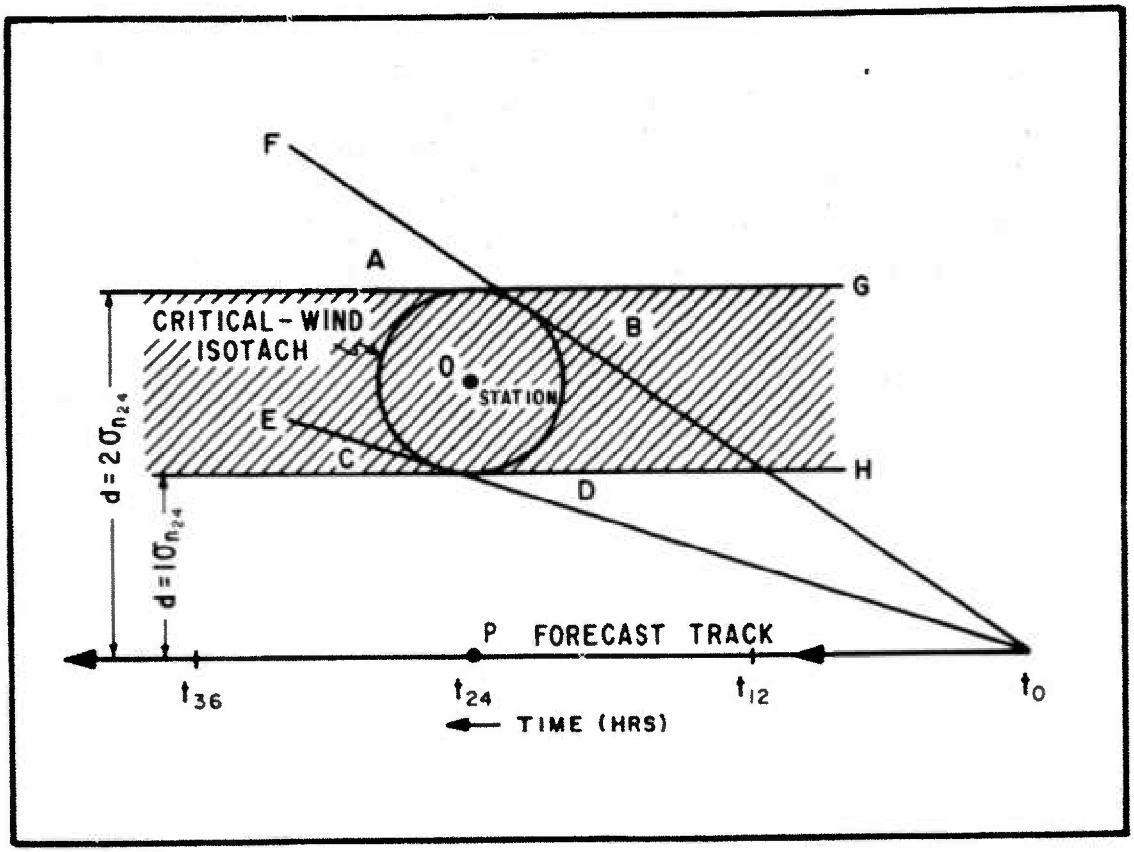

Figure 4 — Probability of storm affecting base with above-critical winds: Example 1.

E and F, which is the information desired. By inspection, it can be seen that area A on Figure 4 would contain approximately the same number of cases as area B. (Note that area A is slightly larger than B, but being further from P will experience a lower probability density than B.) Similarly, areas C and D would contain an approximately similar number of cases. Consequently, the probability of a storm lying between lines E and F at t_{24}, and hence affecting the base at some time during its passage, is about the same as the probability of it lying within the cross-hatched area at t_{24}, or 14%. This is the value of the P_f forecast that would be issued by the forecaster, in this example.

A slightly more complex case is presented in Figure 5. Here, the track is shown as curved and the critical isotach as non-circular (Figure 5a). The storm is forecast to be closest to the station at t_{18}. Before circumscribing the isotach about station Point O (Figure 5b), it was rotated 180 degrees in order to maintain the same distance relationship between the isotach and Point P as originally existed between the isotach and Point O.[2] Again, for simplicity, the distance between Point P and the farthest and nearest points on the isotach is given in whole units of σ_n, i.e., $2\sigma_{n_{18}}$ and $-1\sigma_{n_{18}}$, respectively. Referring to Figure 2(b), it is seen that approximately 48% of the cases lie between the track and $2\sigma_n$, and 34% between

[2] In the preceding example rotation was unnecessary as the isotach was assumed circular and centered about P.

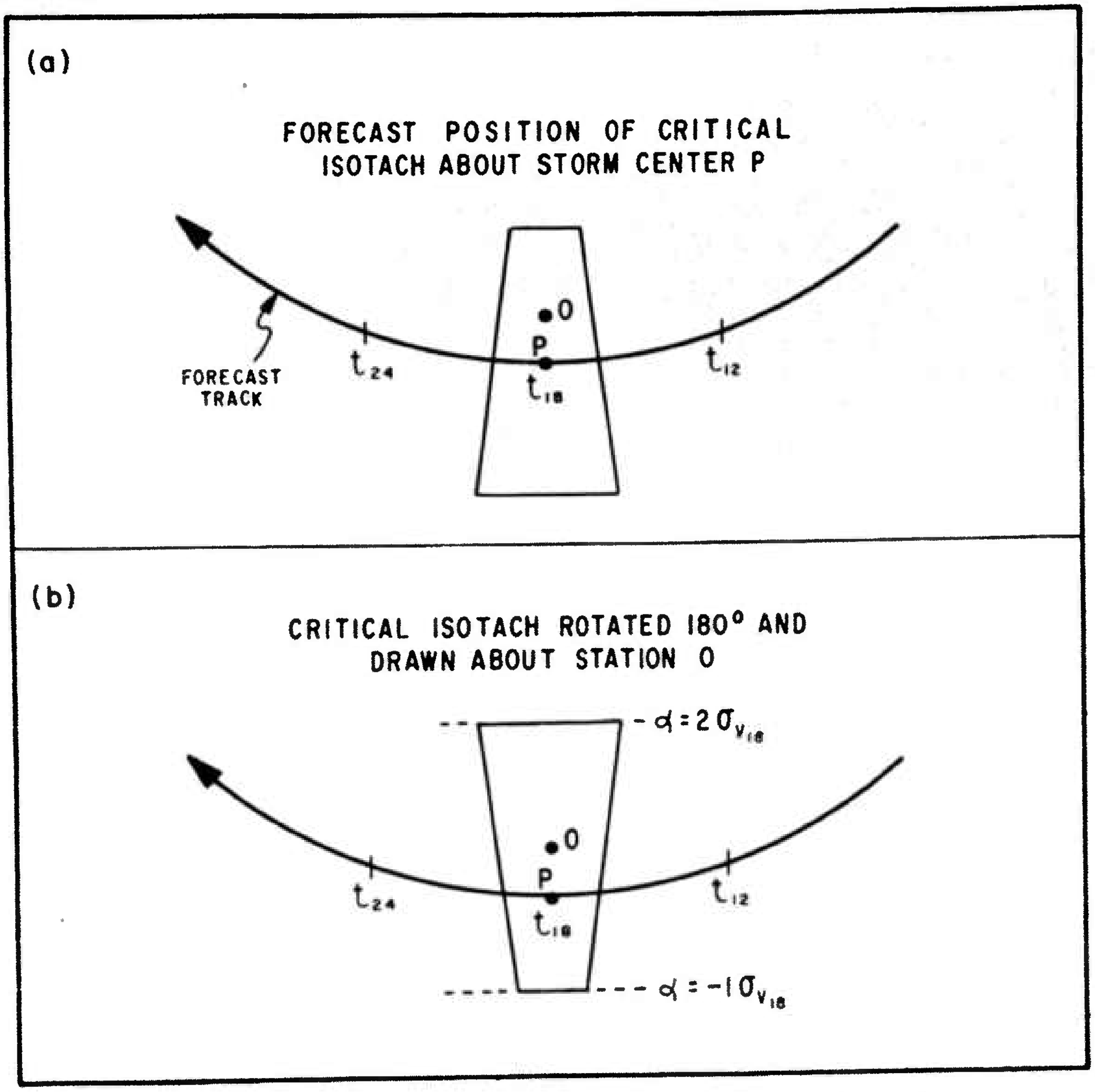

Figure 5 — Probability of storm affecting base with above-critical winds: Example 2.

the track and -1 σ_n. Thus, the total probability of a storm center passing through the critical isotach area is (48 + 34), or 82%. Note that in this example, with the isotach area straddling the track, the two probabilities are added, whereas in the previous example they were subtracted.

Use of Nomograms to Determine Total Probability.

In actual practice, the forecaster measures distances in nautical miles, rather than in units of σ_n. Hence, a set of four nomograms has been prepared to permit a rapid computation of the total probability, one graph for each geographical area listed in Table 1 (see Figures 6 through 9). The x-axis of each nomogram is the number of hours after issuance of the forecast when the storm is expected to be closest to the base. The y-axis is the distance from the track to the nearest and farthest points on the critical isotach at that time. The sloping lines give the probability of the storm passing between the track and these points.

As an example of the use of the nomogram, assume a forecast is issued at 0000Z, 26

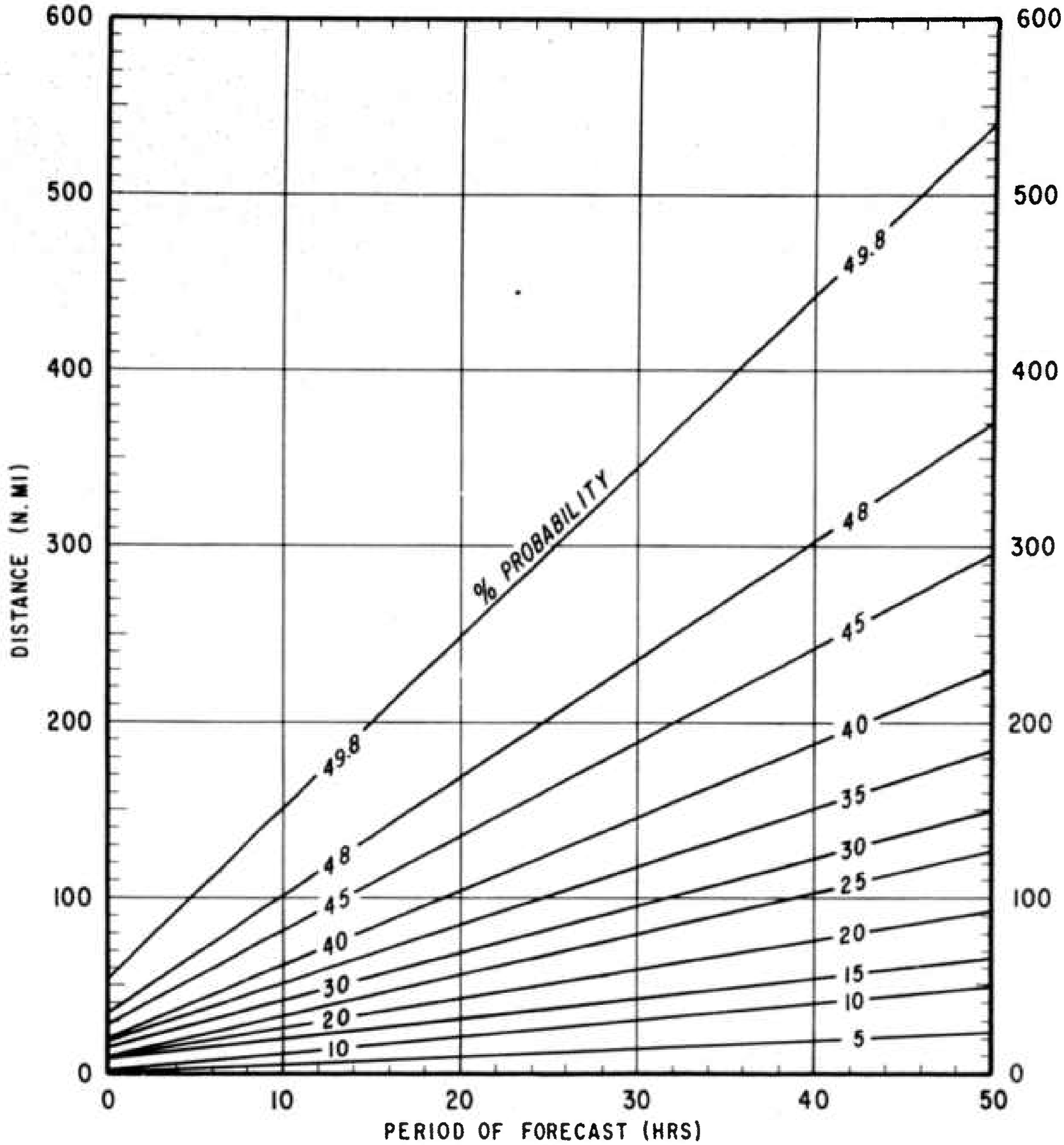

Figure 6 — Nomogram for computing total probability of base being affected by above-critical winds, Atlantic-Caribbean area.

August, indicating that a typhoon center will pass closest to Guam (13°N) at 1200Z the following day (a 36-hour forecast). Using the forecast radius of critical winds, the critical isotach, rotated 180 degrees, is drawn about the station O (Figure 10). It is found that the near and far edges of the isotach are 100 and 300 n. mi., respectively, from the track. Figure 7 shows a 22% probability of the storm passing within 100 n. mi. of either side of the track, and 46% within 300 miles. Thus, the probability of the storm affecting the base is 24%. A new forecast would be issued 12 hours later when new information became available.

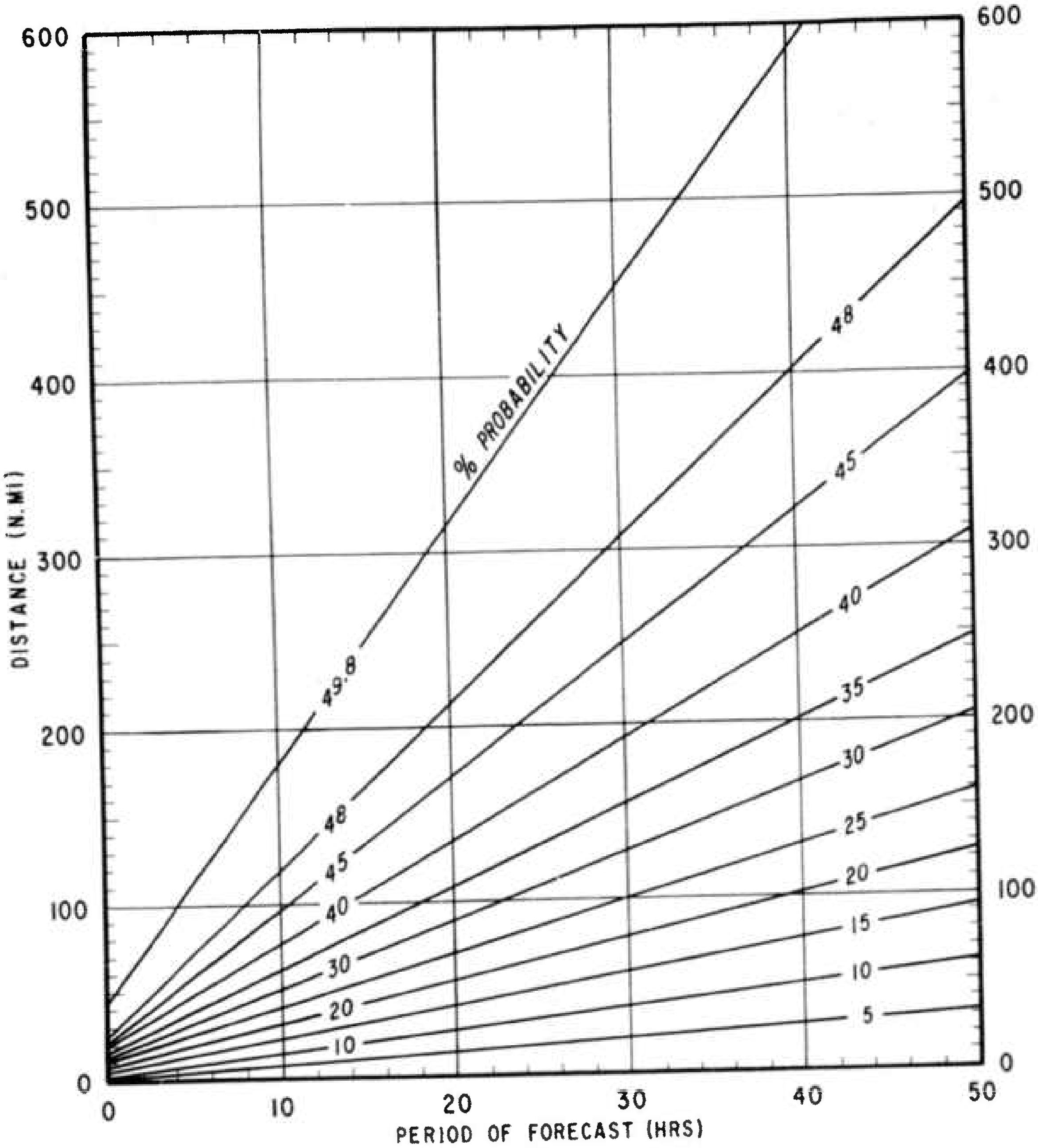

Figure 7 — Nomogram for computing total probability of base being affected by above-critical winds. Pacific area < 20°N.

For ease of computation, the nomograms can be reduced to the scale of the maps used for plotting the forecast cyclone tracks. Distances could then be picked off the map by dividers and read off the nomogram in terms of probability without intermediate conversion into miles. Or, the nomograms can be made into transparent overlays so that the probability values can be read off the map directly.

It may be well to point out once more that if the critical isotach straddles the forecast

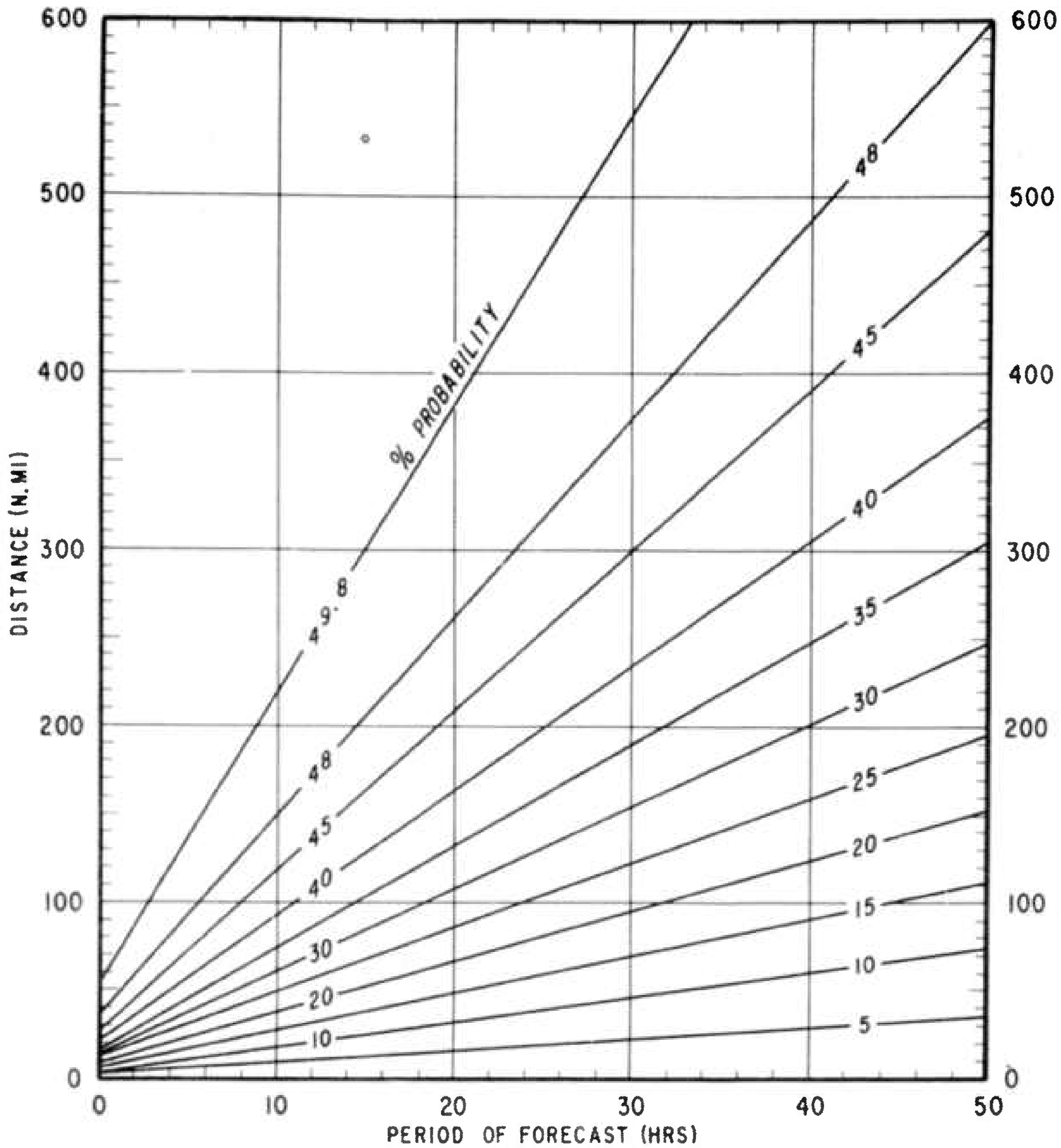

Figure 8 — Nomogram for computing total probability of base being affected by above-critical winds. Pacific area from 20-30°N.

storm track, the two probability values obtained from the nomograms are added to give the total probability. If, on the other hand, the isotach lies entirely to one side of the track, the smaller probability value obtained is subtracted from the larger.

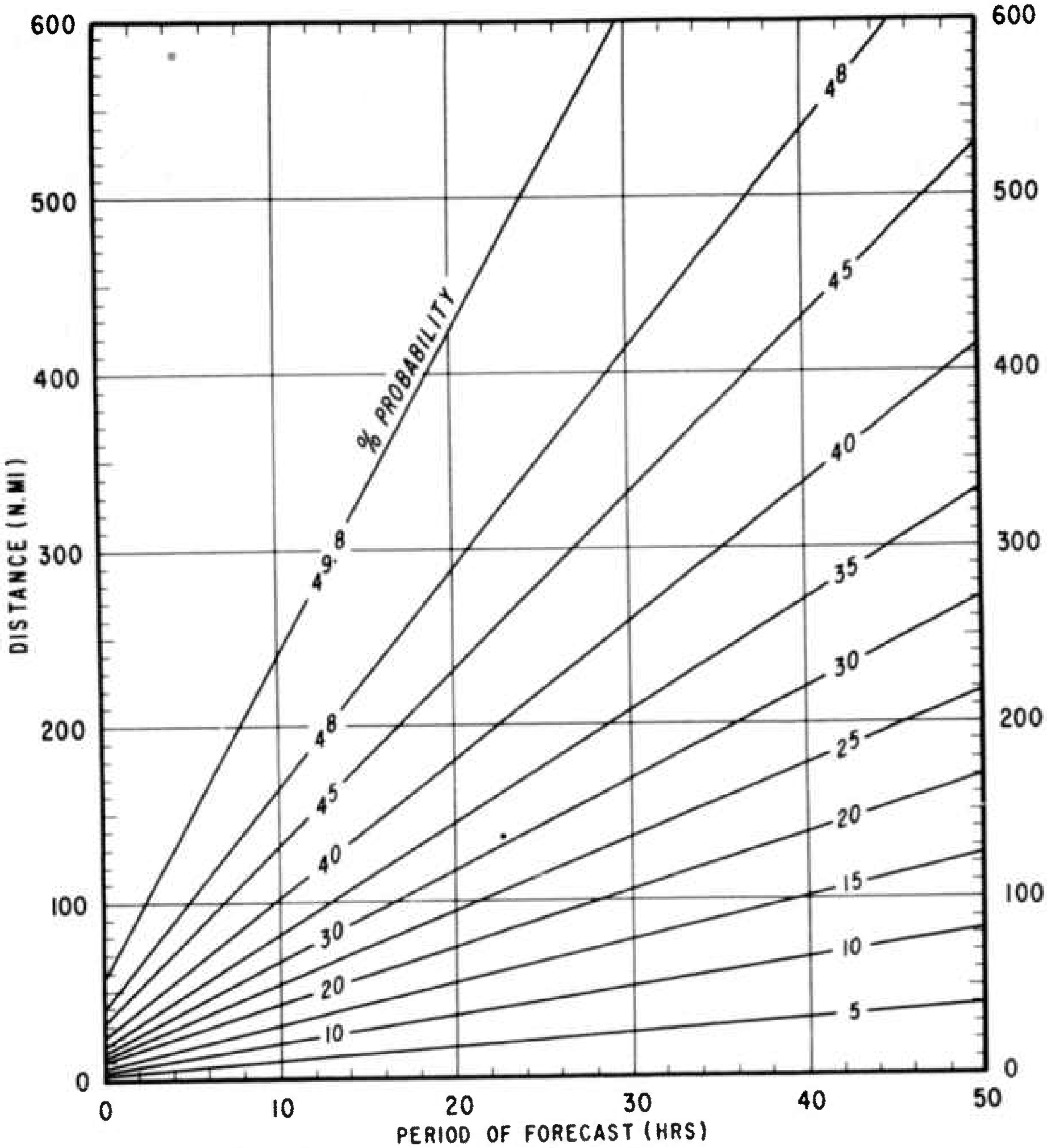

Figure 9 — Nomogram for computing total probability of base being affected by above-critical winds, Pacific area >30°N.

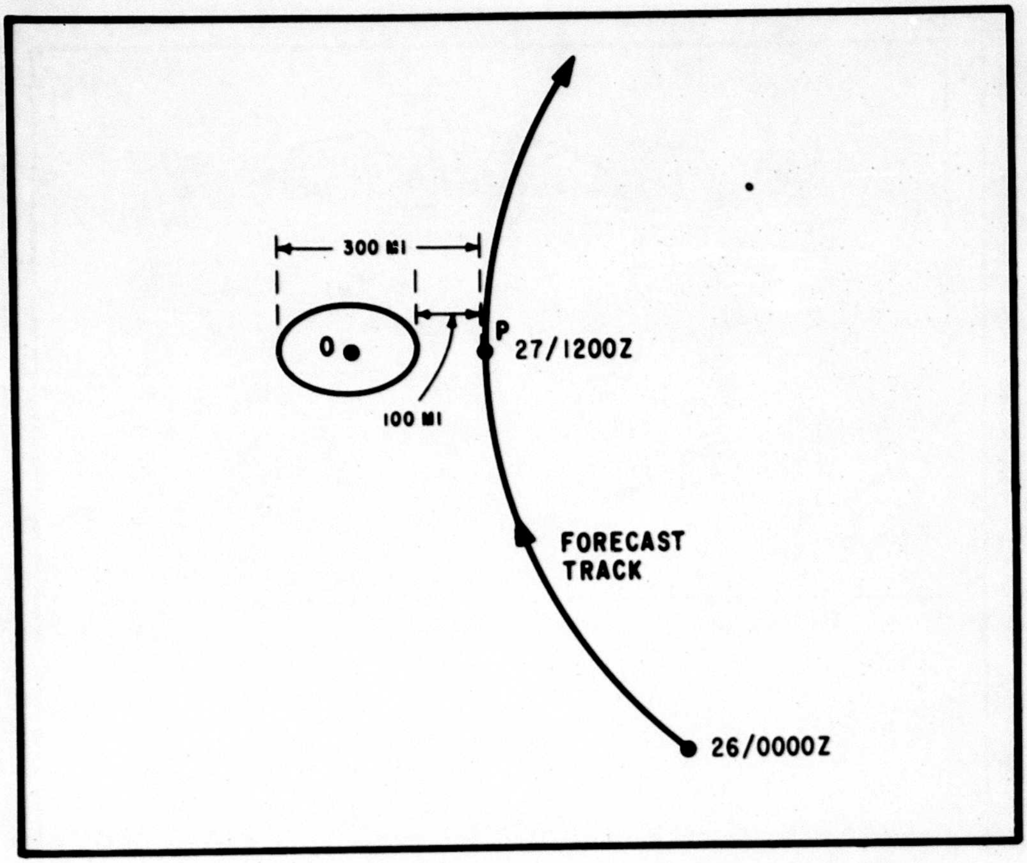

Figure 10 — Example of use of nomogram to determine the total probability of above-critical winds affecting Guam.

SECTION C — THE INSTANTANEOUS PROBABILITY OF ABOVE-CRITICAL WINDS AFFECTING THE BASE

Explanation of the Technique for Determining Instantaneous Probability.

The technique for obtaining the probability of the base being under the influence of above-critical winds at any specific time makes use of the standard vector forecast error, rather than the standard component error used in Section B. Figure 11 shows the observed position of a storm center at time zero (0000Z, 26 August) and the predicted track for the next 30 hours. Point P indicates the forecast position of the storm center at 1200Z, 26 August, while Point O indicates the air base of concern. If a forecast is desired of the probability of the station being affected by above-critical winds at 1200Z, the forecast critical isotach for that time, rotated 180 degrees, is drawn about Point O.

Using P as a center, circles are circumscribed tangent to the nearest and farthest points of the isotach circle (A and B, respectively). For simplicity, the distance from P to A in this example has been made equal to the 12-hour value of the standard vector error (i.e., $r = 1\sigma_{v_{12}}$); Figure 2(a) shows that 64% of the cases will fall within this circle. Similarly, the distance from P to the B circle has been made equal to $2\sigma_{v_{12}}$, and 98% of the cases will fall within this

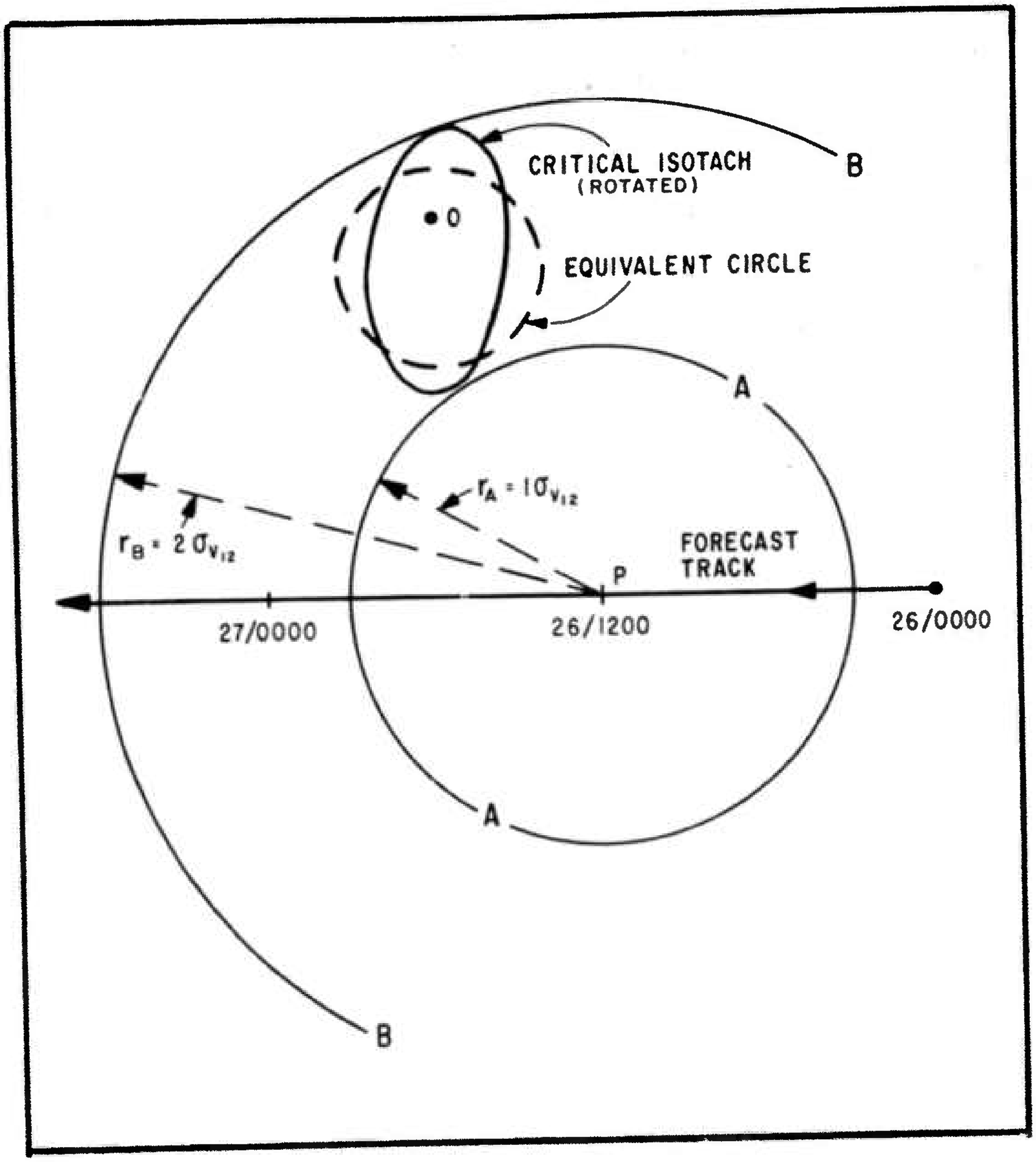

Figure 11 – Computing the instantaneous probability of a station being affected by above-critical winds.

circle. Thus, 34% of the cases will fall within the ring bounded by the A and B circles.

Of the 34% of the cases lying within the ring, only a small fraction *(F)* would lie within the isotach circle. This fraction would be equal to the critical isotach area divided by the area of the ring. The latter is equal to the area of the B circle (α_B) minus the area of the A circle (α_A). The isotach area (α_i), if not already circular, can be approximated sufficiently accurately by replacing it with an equivalent circle. Thus, in Figure 11, $F = \frac{\alpha_i}{\alpha_B - \alpha_A} \approx \frac{1}{18}$, so the probability of the base being under the influence of above-critical winds at 1200Z, 26 August, is $\frac{1}{18} \times 34$, or approximately 2%. In practice, it is desirable to replace the multiplying factor, $\frac{\alpha_i}{\alpha_B - \alpha_A}$, by the corresponding radii equivalents, $\frac{r_i^2}{r_B^2 - r_A^2}$.

Use of Nomograms to Determine the Instantaneous Probability.

The above procedure, too, has been simplified for operational use by the construction of nomograms. Figures 12 through 15 give, for each of the four geographical areas, the probability of the storm center lying within

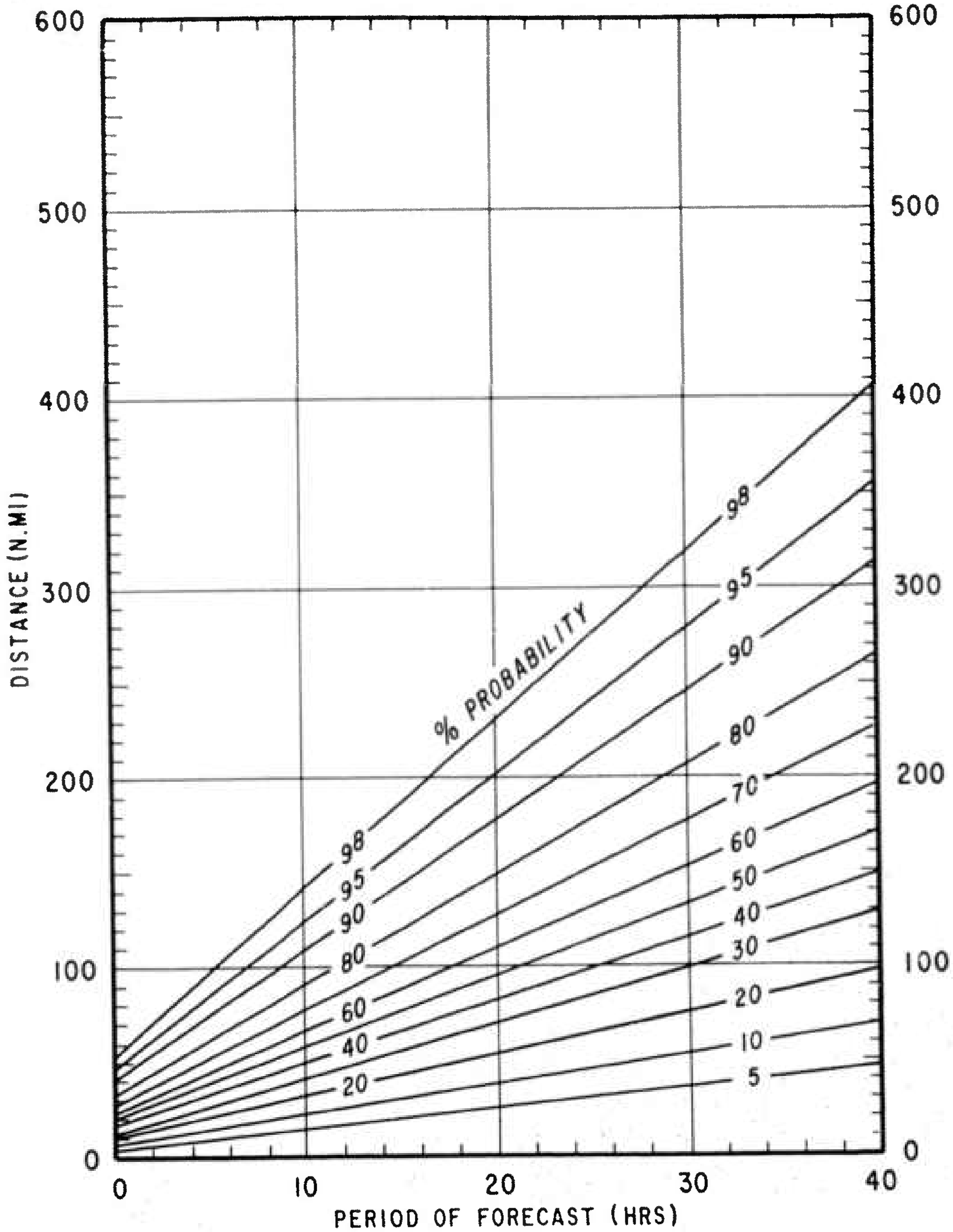

Figure 12 — Nomogram for computing instantaneous probability of a base being affected by above-critical winds, Atlantic-Caribbean area.

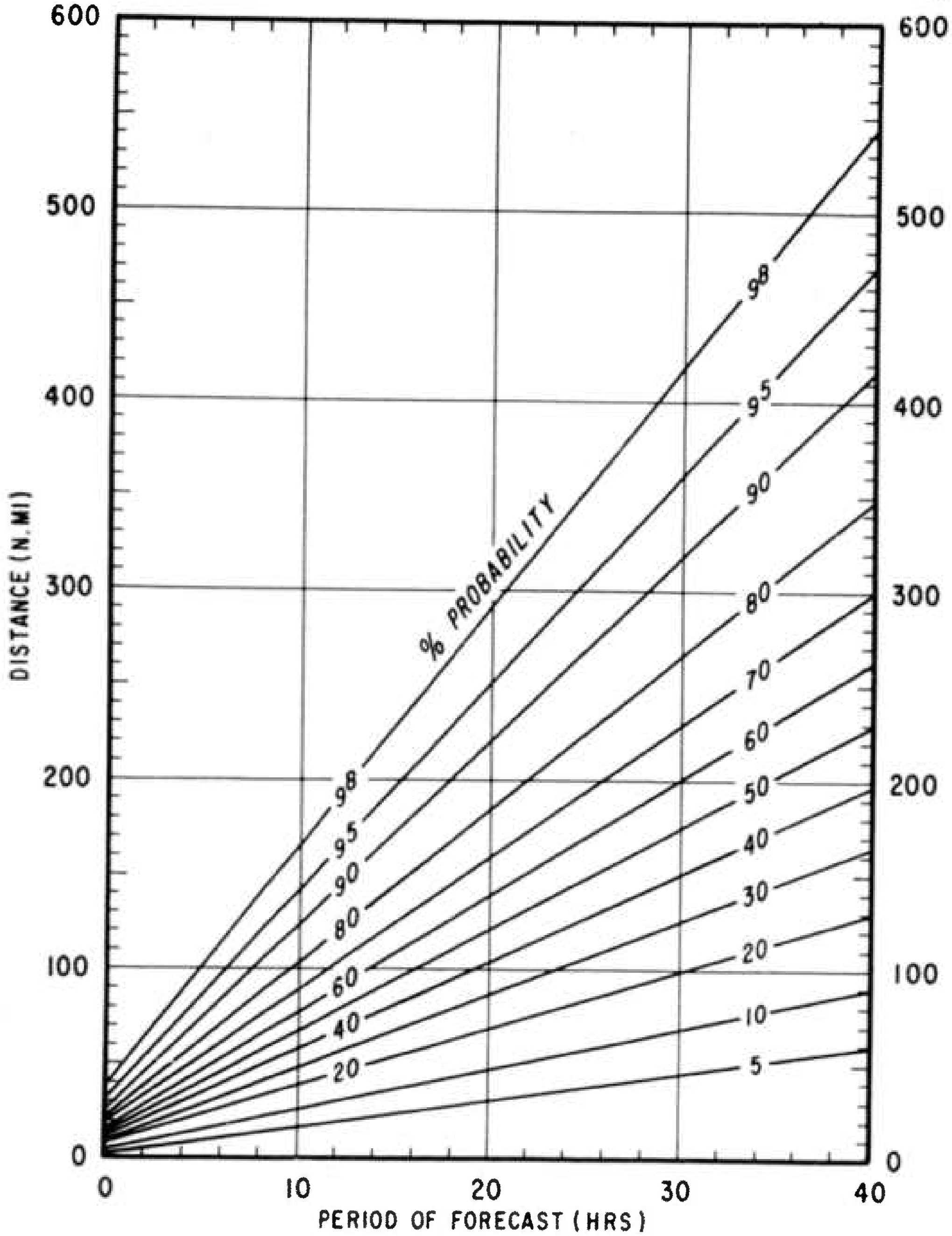

Figure 13 – Nomogram for computing instantaneous probability of a base being affected by above-critical winds, western North Pacific, <20°N.

a circle of radius r from the forecast position of the hurricane center, P. In actual practice, the forecaster measures the distance from P to the nearest and farthest points of the critical isotach circle, reads off the corresponding probabilities from the proper nomogram, and subtracts the smaller from the larger. (If Point P lies inside the critical area, the smaller radius is considered equal to zero.) This gives the probability of the storm center lying within the ring at the time of interest.

Table 2 and Figure 16 enable a more rapid computation of the fraction of cases lying

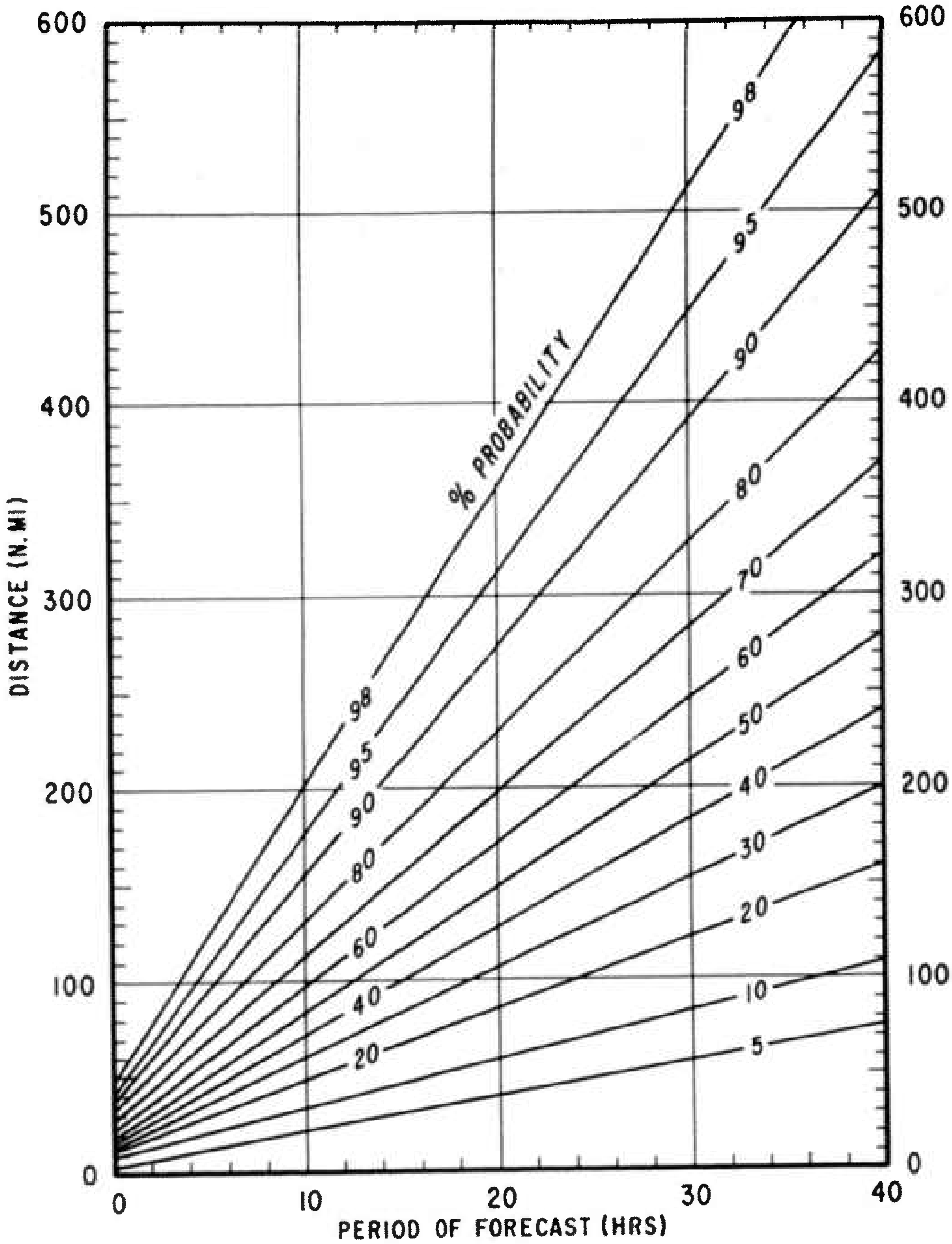

Figure 14 – Nomogram for computing instantaneous probability of a base being affected by above-critical winds, western North Pacific, 20-30°N.

within the critical isotach area. Table 2 is a Table of Squares for obtaining values of r^2 from r, and Figure 16 gives the value of F as a function of r_i^2 and $(r_B^2 - r_A^2)$. The forecaster measures the radii of the two tangent circles (r_A and r_B) and of the circle approximating the critical isotach area (r_i), obtains their squared values from Table 2, and computes the value of the fraction F from Figure 16. He then multiplies the probability of the storm center lying within the ring by F, and thus obtains the probability of the storm center lying within the critical isotach area.

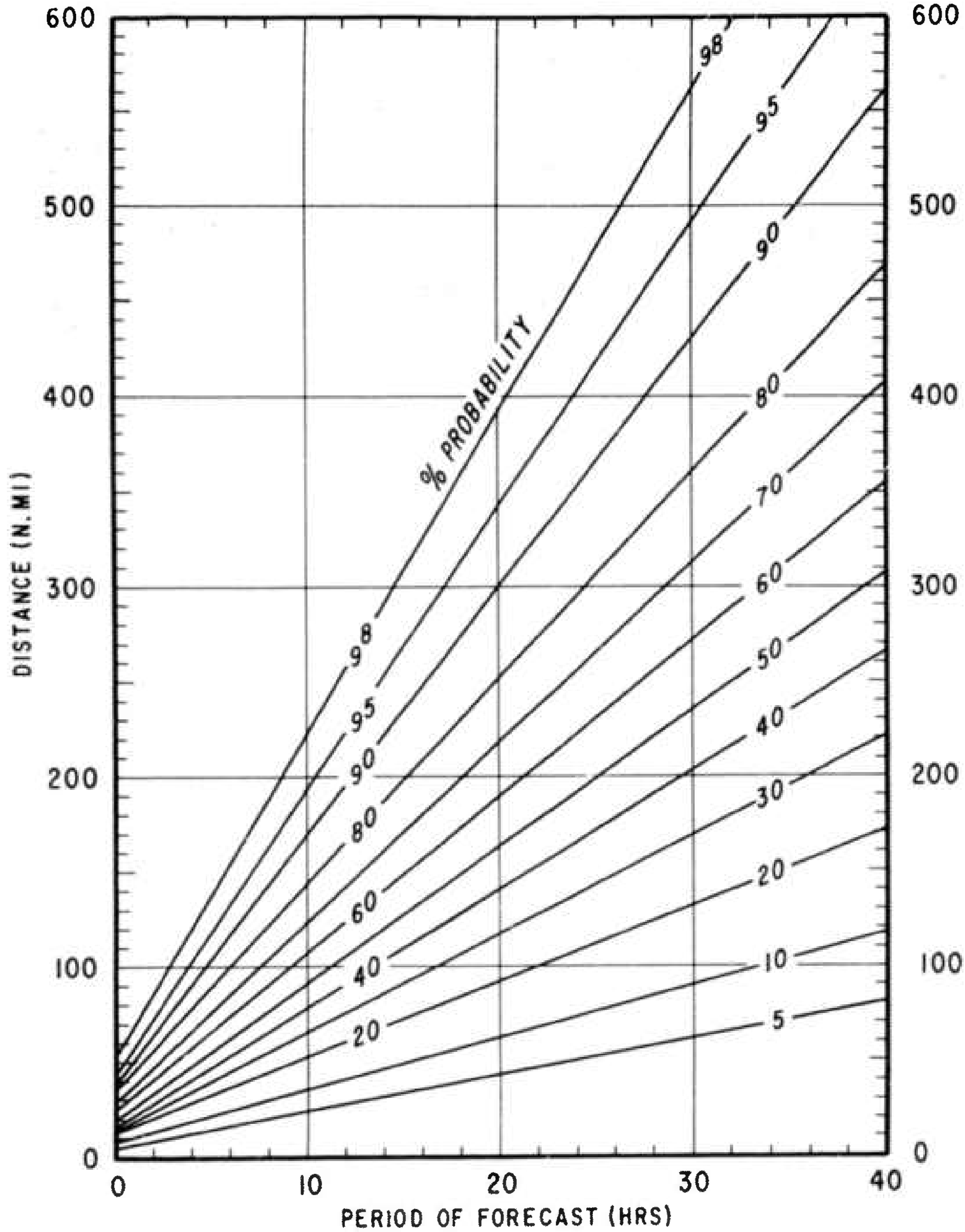

Figure 15 — Nomogram for computing instantaneous probability of a base being affected by above-critical winds, western North Pacific, >30°N.

By using interpolated positions along the predicted storm track, the forecaster can compute the instantaneous probability of the base being under the influence of above-critical winds at successive times throughout the period of interest, e.g., every three hours. Figure 17 shows an example of such a time-probability graph.

TABLE 2

Table of Squares

r	r^2	r	r^2	r	r^2	r	r^2
1	1	26	676	51	2 601	76	5 776
2	4	27	729	52	2 704	77	5 929
3	9	28	784	53	2 809	78	6 084
4	16	29	841	54	2 916	79	6 241
5	25	30	900	55	3 025	80	6 400
6	36	31	961	56	3 136	81	6 561
7	49	32	1 024	57	3 249	82	6 724
8	64	33	1 089	58	3 364	83	6 889
9	81	34	1 156	59	3 481	84	7 056
10	100	35	1 225	60	3 600	85	7 225
11	121	36	1 296	61	3 721	86	7 396
12	144	37	1 369	62	3 844	87	7 569
13	169	38	1 444	63	3 969	88	7 744
14	196	39	1 521	64	4 096	89	7 921
15	225	40	1 600	65	4 225	90	8 100
16	256	41	1 681	66	4 356	91	8 281
17	289	42	1 764	67	4 489	92	8 464
18	324	43	1 849	68	4 624	93	8 649
19	361	44	1 936	69	4 761	94	8 836
20	400	45	2 025	70	4 900	95	9 025
21	441	46	2 116	71	5 041	96	9 216
22	484	47	2 209	72	5 184	97	9 409
23	529	48	2 304	73	5 329	98	9 604
24	576	49	2 401	74	5 476	99	9 801
25	625	50	2 500	75	5 625	100	10 000

For values of r greater than 100, replace r by $r/10$, and multiply resulting value of r^2 by 100.

SECTION D — A COMPARISON OF TOTAL AND INSTANTANEOUS PROBABILITIES OF ABOVE-CRITICAL WINDS AFFECTING THE BASE

A comparison of the two types of probabilities for the same storm is given in Figure 18. Assume a forecast is issued at 1200Z, 27 August. It is seen that the storm center is predicted to pass nearest the base at 1200Z, 28 August (24 hours after forecast time). If this is a Caribbean hurricane, the total probability would be obtained from Figure 6. The rotated critical-wind isotach is drawn about the station Point O. The distances from P to the nearest and farthest points of the isotach are 50 and 150 miles, respectively. The intersection of the 24-hour vertical line on the graph, Figure 6, with the

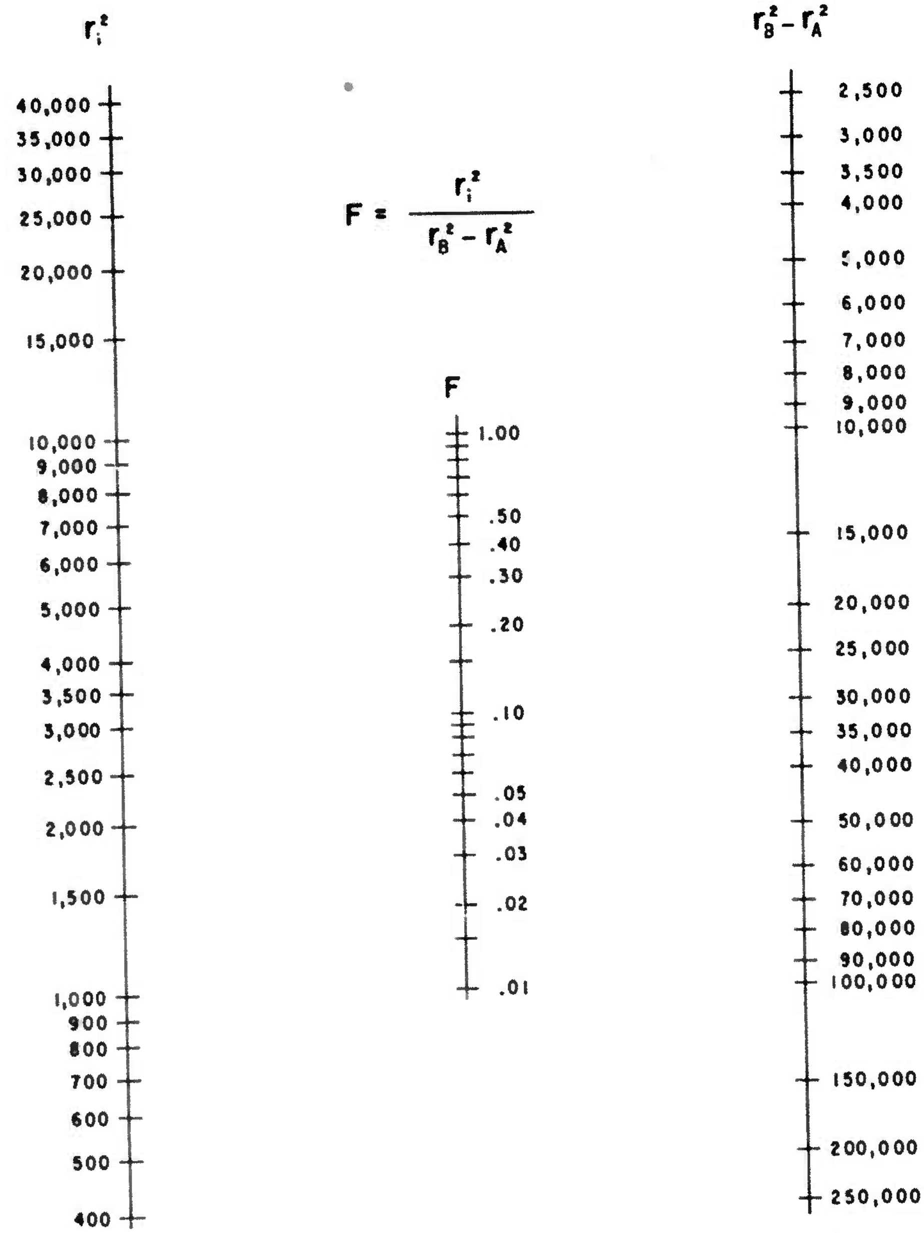

Figure 16 — Nomogram for computing F. Lay straight edge across proper values of r_i^2 and $r_B^2 - r_A^2$, then read F at intersection of straight edge with central column.

50- and 150-mile horizontal lines gives probability values of 20 and 44%, respectively, or an overall probability of 24% that the station will be affected by above-critical winds at some time during the passage of the storm.

The instantaneous probability of the station being under the influence of above-critical winds at 1200Z, 28 August, is obtained from Figures 12, 16, and Table 2. Figure 12 shows that the probability of the storm center lying within the 50-mile circle on a 24-hour

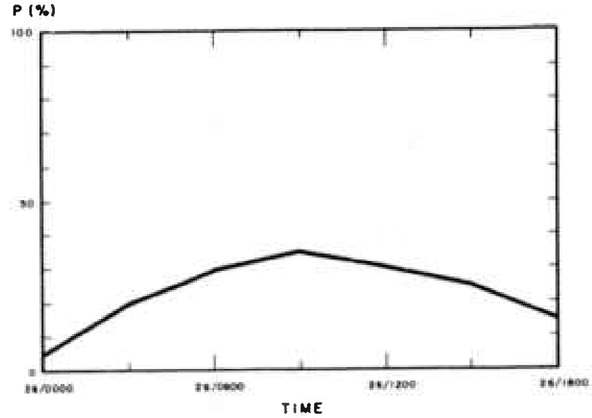

Figure 17 — Example of probability of typhoon winds above 50 knots at Kadena Air Base, Okinawa, as a function of time.

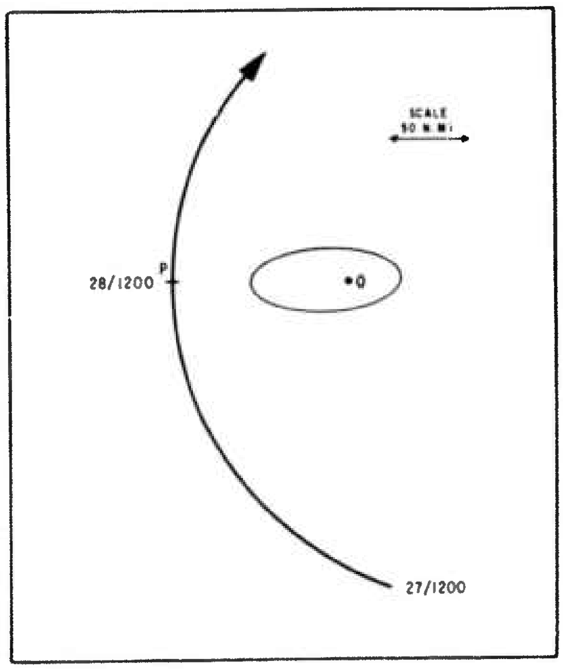

Figure 18 — An example of a comparison of total and instantaneous probabilities.

forecast is 13%, and within the 150-mile circle, 71%. Thus, the probability of the storm center lying within the ring is 58%. The radius of a circle equivalent in area to the critical isotach is 35 miles. Table 2 gives the values of r_i^2, r_A^2, and r_B^2 as 1225, 2500, and 22,500, respectively. Since $(r_B^2 - r_A^2)$ equals 20,000, Figure 16 gives the value of F as about 0.06. Multiplying 58% by 0.06 gives a 3.5% probability that the station will be under the influence of above-critical winds at 1200Z, 28 August, as compared with the total probability of 24% of being affected at some time during the storm's passage.

SECTION E — THE OPERATIONAL APPLICATION OF PROBABILITY FORECASTS

It may be that the various commanders on the base will either have or wish to formulate plans that are put into operation when the probability of the base being struck by above-critical wind speeds exceeds a certain value. In order to determine such a criterion, it is necessary to balance the cost of protection — such as tying down or evacuating aircraft, removing missiles from firing sites, delaying certain operations, etc., — against the cost of damage when protective steps are not taken. A number of papers have been published regarding this problem [3][4][5][6].

As a simple example, if protective action costs $100,000, and the damage to an unprotected base from a hurricane can be expected to average $1,000,000, it is clear that protective action should be taken whenever the probability of the base being hit exceeds 10%. Normally, the actual start of such action should be delayed as long as feasible in order to permit the probability forecast to be based on the latest available data.

Obviously, there are many operations which cannot be measured directly in dollars and cents. For instance, improvements in the design of a missile might have to wait on the results of a test firing. Removing a missile from its firing pad might result in a long delay before the missile could again be positioned for testing. In such cases, it might be determined that the value to be gained from acquiring earlier data is worth the risk of missile damage or destruction, particularly if a standby missile is available.

Although not all operations can be measured in terms of money, it is still necessary to put their values on a common basis in order to make objective decisions. Such an evaluation cannot, of course, be made by the forecaster, but only by the commander (or his representative) concerned with the operation. By proper weighting of all factors involved, it should be possible for the commander to determine the value of the forecast probability that would set the operational plan into action (see Part B, Section 5 [3]).

SECTION F — REFERENCES

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